In addition, the losses to lumber interests (no estimate of which has been obtained) were undoubtedly great. It is reported that "one large company alone sustained a loss in production of several million feet, the mill having been closed down for more than 12 weeks."

The flood was the cause of four deaths in this district.

In all sections affected by overflow the delay to planting consequent upon the extreme lateness of the drainage of overflowed land was a very serious feature of the flood. This point is concisely covered in the Memphis station report: "In the upper part of this district it is stated that cotton will not mature if planted after June 1, and in the greater portion of the lower part it should be planted not later than June 10. As the land in the overflowed area was still submerged after these dates, it is reliably estimated that not more than one-half a crop can be raised this year—and not that much should there be an early frost."

In the Vicksburg district, as in the Memphis, the losses were in very large part to crops and prospective crops. The following is quoted from the report of the official in charge of the Vicksburg station:

Of the 860,000 acres overflowed in the lower Yazoo Basin from Mississippi River backwater much formerly under cultivation has been abandoned as agricultural land on account of the relative frequency of flooded conditions thereon during recent years.

Exact figures are not extant as to the acreage in the lower Yazoo Basin that would have been devoted to staple crops during 1929 had a flood not intervened; it is thought that 250,000 acres is a conservative estimate.

Much of the land overflowed and intended for crops the present season has been planted subsequent to the subsidence of the water therefrom. The returns from these crops will depend upon the kind of weather following and the prices to be obtained. Compared with the price that might be obtained from crops originally intended to be planted on this land, a loss of about $10 an acre is probable, making a loss of $2,500,000 on the agricultural land overflowed.

A tabulated loss was sustained by railroad companies in this district in protecting their property against flood damage, amounting to $51,901.26; intangible losses also occurred, difficult to enumerate, such as moving refugees, the abandonment of a branch line 45 miles in length from March 21 to July 15, and other losses due thereto.

There was also a considerable though undetermined loss in this district owing to the suspension of business activities.

The damage done in St. Martin Parish by the overflow from crevasse No. 2 (see above) was confined to the inconvenience and expense of moving several hundred families to safety and to an undetermined but probably not great loss owing to the delay in the use of the land for planting.

Savings by warnings.—In the Mississippi Valley, where the high standard of accuracy of flood warnings has long since established their dependability, and where predictions can be made so long in advance of impending conditions that their application reaches to some extent practically every activity in the valley, they have an importance which is, quite literally, immeasurable. As a flood year 1929 is no exception as an example of the widespread use of these warnings or of the difficulty of placing a value upon them. The Vicksburg district report states that "their value must have been considerable, but impossible of accurate tabulation"; and the official in charge of the Memphis station remarks as follows:

The estimated money value of property saved by the flood warnings was $786,000. Of those reporting flood losses and savings resulting from the flood warnings, many stated that it was impossible to place a dollar valuation on the savings due to the warnings. That the amount given above is far below the actual savings is indicated by the following remarks by those reporting:

"Impossible to estimate, but without such warnings loss of life and property would have been great."

"There is hardly any way of estimating the worth of flood warnings. They are so necessary that we could not exist without them."

The warnings were distributed by radio, telegraph, telephone, and mail, including distribution by the daily press, which gave much space to river news. Levee engineers and contractors, planters, lumber companies, and others in the threatened region called daily by long distance telephone for the forecasts and river stages. Many additional copies of the river bulletin were distributed by boats at way landings.

WEATHER ABNORMALTIES IN THE UNITED STATES

EXCESSIVE RAINS AND FLOODS IN SOUTHEAST ALABAMA

551.577.3 (761)

ALFRED J. HENRY

(FOURTH NOTE)

The most extraordinary floods in perhaps a century or more occurred in the streams of southeast Alabama, in March, 1929.

An account of these floods was given in this REVIEW for that month. In the haste necessary to the printing of that issue on schedule it was not possible to present a number of details that are essential to a proper understanding of the phenomenon.

Two river systems were involved—the Choctawhatchee and the Escambia. The most spectacular flood was that which submerged the town of Elba, at the junction of the Pea River and Whitewater Creek. The Pea River, a stream probably unknown outside the limits of the State is the main tributary of the Choctawhatchee. The width of Pea River at low water is 150 feet; at bankful stage 225 feet. The Pea River north of Elba where it unites with Whitewater Creek is about 100 feet wide at low water; Whitewater Creek drains a larger area north of Elba than does the Pea River.

The drainage of southeast Alabama is wholly to the Gulf of Mexico through a number of streams, naming them in order from east to west, the Chattahoochee, although it carries a relatively small amount of Alabama drainage would come first, then follows the Choctawhatchee and its main tributary the Pea. Next in order and importance is the Escambia with its chief tributary, the Conecuh entirely within Alabama. All of these streams originate in the Coastal Plain of Alabama which gradually slopes from about 600 feet in the north to Gulf level.

A map, Figure 1, shows the streams-above mentioned and the location of rainfall stations in the several basins. The 100 and 500 foot contour lines are given. The latter barely touches the headwaters of the Pea, about 125 miles from the Gulf of Mexico. The slope is therefore one quarter of a foot per mile.

The rains which led up to the floods began on February 27, continued on the 28th, and then ceased until March 4–5, when a second period of heavy rains set in. Beginning on the 12th a third and the most intense of the four periods began. The rains of this period culminated on the 15th as may be seen from the tabulation below. While torrential downpours occurred in southern Alabama the rainfall of the entire State was the most extraordinary in the last 50-odd years, if not in a century. The *average* of the northern part of the State as deduced from the records of 25 stations was 12.02 inches; for the southern half with 47 stations it was 17.12 inches, and for the State as a whole with its 52,000 square miles of area, the *average* was 15.35 inches or 9.60 inches greater than normal.

We are more particularly interested, however, in the daily amounts at stations in and near the basins of the two river systems involved. I therefore show in the table next following the 24-hour rainfall at those stations and from the data of that table an isohyetal chart giving the total rainfall in the two basins for March 12–16 as show in in Table 2 is superposed on Figure 1.

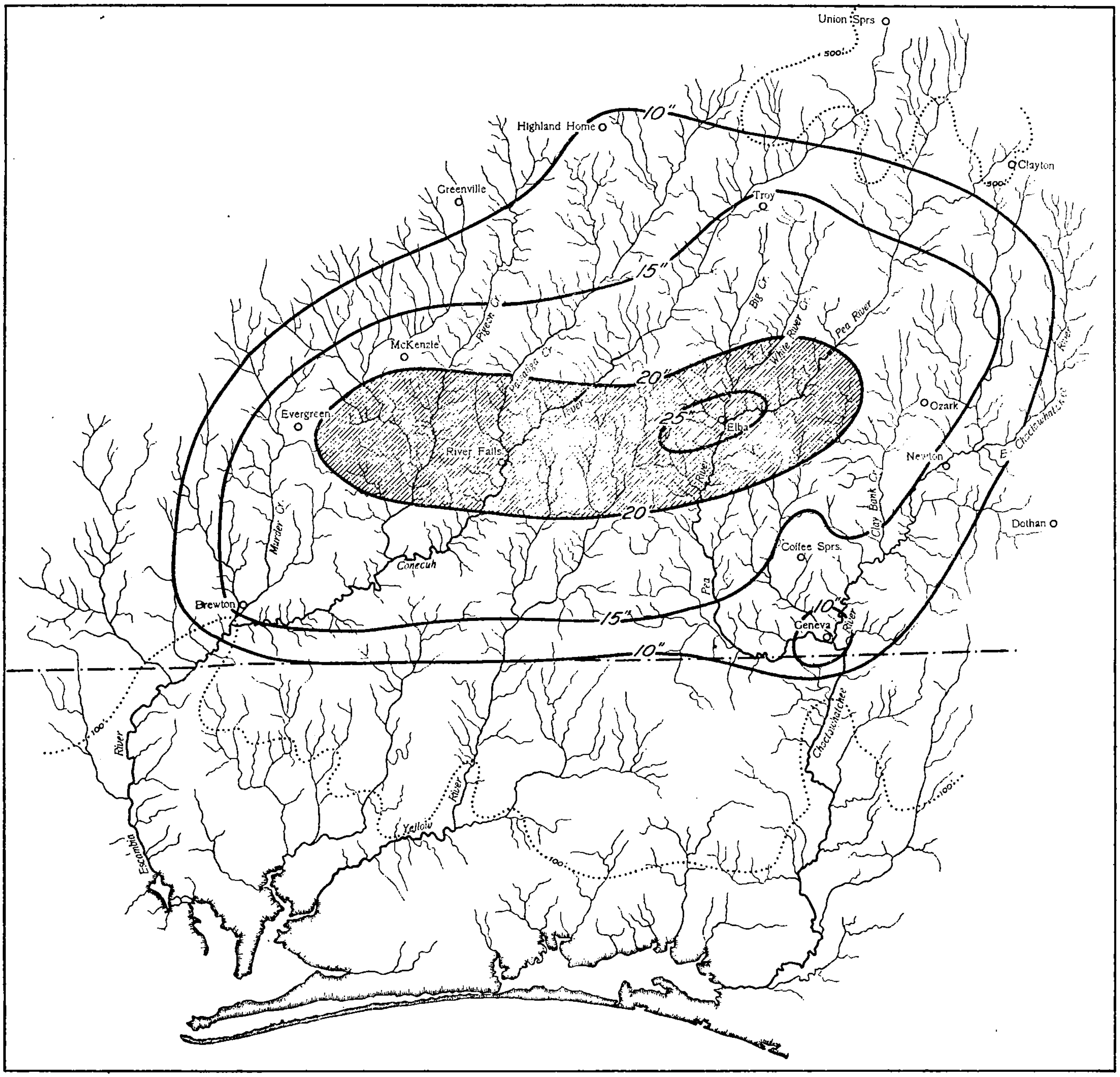

FIGURE 1.—Map of Choctawhatchie and Conecuh River basins with contour lines and total rainfall March 12–16 superposed

TABLE 1.—*Average rainfall in Alabama on the dates named (inches and hundredths).*

Dates	Amounts	Dates	Amounts	Dates	Amounts
Feb. 26	1.97	Mar. 5	1.40	Mar. 15	4.89
Feb. 27	2.43	Mar. 12	.81	Mar. 22	.76
Feb. 28	1.10	Mar. 13	1.93	Mar. 23	.77
Mar. 4	2.28	Mar. 14	4.70		

The rainfall map when considered in connection with the fact that the ground was saturated with water from the rains immediately preceding those shown on the charts make it clear why so great a quantity of water descended on the towns of Elba and Brewton, for example. The position of Elba at the junction of Whitewater and Big Creeks with the Pea River must have been a large factor in the water concentration. In the case

FIGURE 2.—Airplane view of the flooded town of Elba, Ala., March 15, 1929. (Photo by Fourth Photographic Section, Air Corps, Maxwell Field, Montgomery, Ala.)

FIGURE 3.—Airplane view of the flooded town of Brewton, Ala., March 15, 1929. (Photo by Fourth Photographic Section, Air Corps, Maxwell Field, Montgomery, Ala.)

of Brewton on the lower Conecuh River, the local drainage at that place also conspired with the heavy rains to send a flood of water into the streams that converge a short distance below the town. Airplane views show the flood situation at both these places (figs. 2 and 3).

Table No. 2.—*Daily precipitation in the basins of the Choctawhatchee and Conecuh River systems for the dates given* [1]

Stations	Altitude, feet	Mar. 12	Mar. 13	Mar. 14	Mar. 15	Mar. 16	Total
Choctawhatchee:							
Elba	2.04	-------	2.20	7.40	20.00	-------	29.60
Clayton	5.89	0.12	1.02	2.07	5.61	0.09	8.91
Dothan	-------	1.11	.66	9.00	2.68	-------	13.45
Ozark	4.00	.10	1.02	3.00	13.40	.05	17.57
Newton	2.16	.30	.67	1.71	11.80	-------	14.48
Union Springs	4.85	.05	2.30	2.65	3.04	-------	8.04
Conecuh:							
Highland Home	(?)	1.32	2.00	5.75	3.10	-------	12.17
McKenzie	4.51	.20	3.30	8.00	8.25	-------	19.75
Troy No. 1	5.81	1.40	2.35	8.00	4.00	-------	15.75
Greenville	4.44	.32	2.64	2.40	3.10	-------	8.46
Brewton No. 2	.85	-------	2.43	.83	13.00	-------	16.26
Evergreen	2.85	.15	2.85	8.70	7.76	-------	19.46
Geneva	1.07	T.	1.30	1.90	11.00	1.00	14.20
River Falls	1.59	T.	3.00	6.03	11.20	-------	20.23

[1] Precipitation at the above stations is measured in the morning except at Troy No. 1 and Highland Home, where it is measured late in the afternoon.

Practically all of southeastern Alabama and the contiguous part of Florida is low country, a coastal strip in Florida that ranges in width from 20 to 60 miles is less than 100 feet above mean Gulf level (see the contour lines in fig. 1). The 500-foot contour barely reaches the headwaters of the Pea River and we are probably justified in saying that the orographic features of southern Alabama are without pronounced influence upon the rainfall of that section.

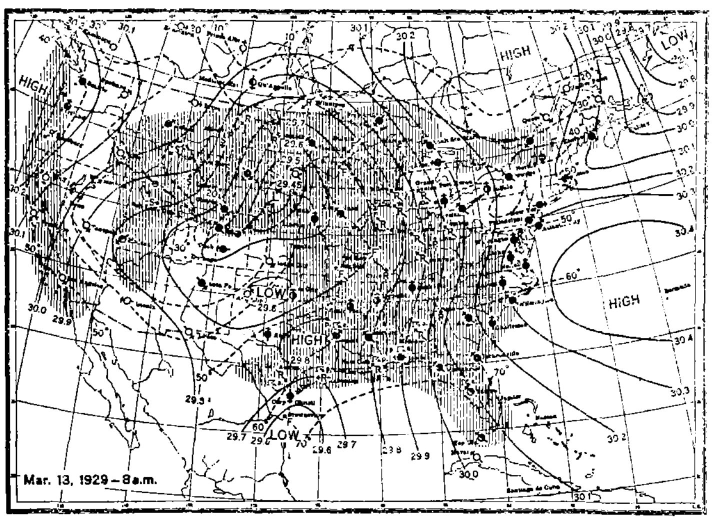

Figure 4.—Weather Map, March 13, 1929—Isobars in full, isotherms in dashed lines; precipitation in last 24-hours shown by vertical shading. The state of the weather at time of observation is shown by the shading of the small circles; no shading indicates clear skies and complete shading cloudy sky; the letter R when combined with the wind-direction arrows indicates that rain is falling at time of observation

Certain limited areas, however, received much greater amounts than others closely surrounding, thus Dothan in Houston County, recorded a rainfall of 9 inches on the 14th when Newton, about 14 miles, to the northwest received but 1.71 inches. Mobile at the head of the bay of the same name measured a 24-hour rainfall of 10.71 inches on the 14th whereas the fall at Pensacola, about 60 miles to the southeast, registered but 0.09 inch and the total for the month of March was but 6.42 inches.

The area of heavy rains is elliptical in shape, with a maximum length of about 100 miles and a width at the widest point of about 20 miles.

As to the cause of the heavy rains on the 14th and 15th of March, the best that can be said is that they were not due to surface relief, neither is the assumption of a convergence of air streams tenable; thus we are left with the distribution of temperature in the vertical as the only reasonable alternative. Nothing is known of the vertical temperature gradient, although a kite flight on the 14th made at Due West, S. C., distant several hundred miles from the area of heavy rain, showed an inversion of temperature throughout the first 500 meters, practically an adiabatic lapse rate (0.91° C.) for the next 800 meters and 0.84° C. throughout the remaining 1,000 meters. Whatever the explanation, the facts are that heavy local

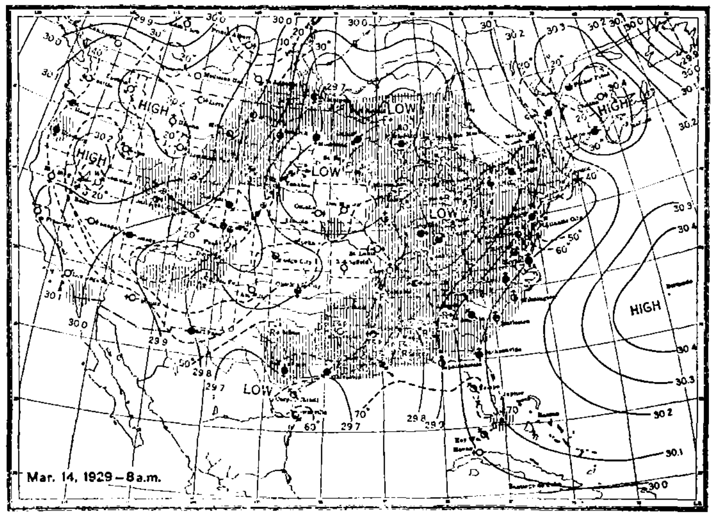

Figure 5.—Weather Map, March 14, 1929

downpours occur with sufficient frequency to be taken into account in planning flood protection measures and finally in planning or selecting sites for settlement along any stream, a site at which a great volume of discharge will converge should either be avoided entirely or properly safeguarded.

THE WEATHER MAPS

The weather maps prior to and during the days with heavy rain have been examined with the following results. The maps for the four groups of days with heavy rains show considerable similarity there being in each case a strong oceanic anticyclone centered over the western part of the North Atlantic in the vicinity of the Bermudas and concurrently therewith on two out of four of the groups there was a great shallow barometric depression or a trough of low pressure over the continent immediately to the westward of the oceanic anticyclone. This pressure distribution is favorable to rain in the Gulf States whenever a cyclonic system approaches from the west of the continent. Without further dwelling on this feature I call attention to the three weather maps reproduced as Figures 4, 5, and 6. The first of these shows a pronounced oceanic anticyclone with central pressure of 30.48 inches at Hamilton, Bermuda. This anticyclone controls the winds of eastern United States, one might say regardless of the pressure distribution over the continent, which in this case joins with the oceanic anticyclone in causing a broad sheet or mass of oceanic air to flow from southeast to northwest over a very large area as may be seen from the map. It is further emphasized that the cyclonic system over Nebraska has made a sharp turn towards the northeast in the 24 hours immediately preceding the morning of the 13th. As a result, for reasons which need not be entered into, two secondary cyclonic systems or preferably, we may call them, barometric depressions are in course of development, one over Oklahoma, the other over the mouth of the Rio Grande.

In the great stream of air moving from southeast to northwest as shown on the map for the 13th there will be places where the rainfall will be greater than at others. The reasons why this is so are not always or indeed often apparent; it may be said in passing that features of surface relief tend to produce heavy rainfall, or regions over which air streams converge will also receive heavy rains, but by far and large vertical convection is the great producer of intense local heavy rains. On the map in question the greatest 24-hour rains were at the following named places:

	Inches		Inches
Pensacola, Fla	2. 90	New Orleans, La	1. 32
Mobile, Ala	2. 58	Palestine, Tex	1. 52
Montgomery, Ala	2. 08	Galveston, Tex	1. 56
Meridian, Miss	1. 42	Dallas, Tex	1. 26

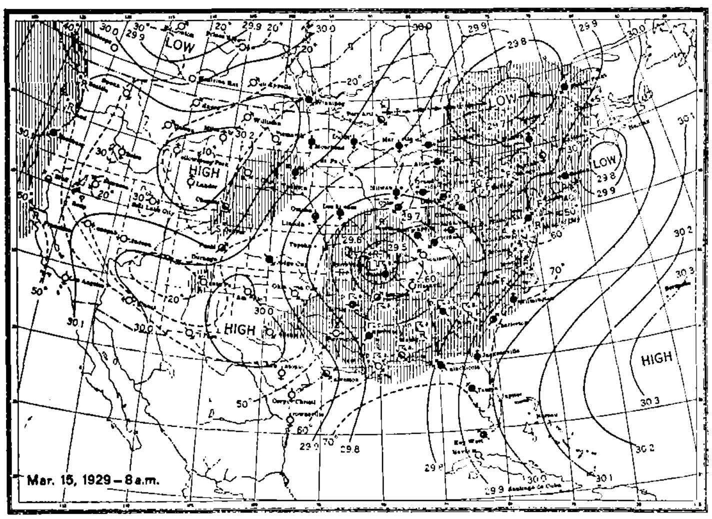

FIGURE 6.—Weather Map, March 15, 1929

On the ground that the atmosphere above stations situated on the coast should contain a greater quantity of moisture than the air far from the coast and therefore the rainfall at coastal stations should be greater than inland ones, we should expect the greater rains to be at coastal stations. This expectation is only partly justified. It can be shown that points in the middle of the continent of North America may and do have as great short period rains as points immediately on the coast.

While the rainfall of the 13th is not in itself noteworthy the weather map has been reproduced to show the change in surface pressure that took place in the succeeding 24 hours.

From Figure 5, weather map of March 14, it is seen that the oceanic anticyclone is still the dominating element in pressure distribution and that by reason of its static qualities pressure to the westward over the continent is apparently greatly disorganized.

There is a great shallow depression covering the Lake region and the Northwest with three centers of low pressure. The isobar of 29.8 inches makes a bend northward from the Gulf of Mexico into Alabama and this loop may be an indication of the northeastward spread of the secondary that on the 13th was centered over the mouth of the Rio Grande.

The rainfall for the 24 hours ending with 8 a. m. seventy-fifth meridian time on March 14, when the map was issued, is available only for the stations of the bureau that telegraph their observations to a central point. Following are the largest amounts on that date:

	Inches		Inches
Asheville, N. C	1. 62	Vicksburg, Miss	2. 68
Atlanta, Ga	2. 12	New Orleans, La	1. 22
Mobile, Ala	3. 98	Knoxville, Tenn	1. 24
Montgomery, Ala	3. 16	Chattanooga, Tenn	3. 66
Birmingham, Ala	4. 12		

At two stations in the general rain area—Augusta, Ga., and Columbia, S. C.—no rain fell and the rain at surrounding stations in that region was very light.

Out of the apparently chaotic pressure distribution of the 14th there arose, as may be seen from the weather map for the 15th, Figure 6, a perfectly organized cyclonic system with central pressure of 29.38 inches at St. Louis, Mo., a fall of 0.36 inch in 24 hours and also a further development of cyclonic activity over Canada southeast of Hudson Bay. These developments are particularly interesting from the dynamical viewpoint but in the absence of definite information as to the method of origin the matter is passed over without further comment. The result of the development, however, was the termination of the rainy period in the Gulf States; these rains did not cease before vast quantities of water were precipitated over Alabama and contiguous States. The greatest falls for the 24 hours ending at 8 a. m., seventy-fifth meridian time, March 15, giving the stations from north to south having 1 inch or more are as follows:

	Inches		Inches
Greenville, S. C	1. 36	Montgomery, Ala	2. 82
Atlanta, Ga	2. 26	Meridian, Miss	2. 00
Thomasville, Ga	4. 64	Mobile, Ala	8. 92
Birmingham, Ala	1. 40	New Orleans, La	1. 08

Unfortunately I am not able to extend these tables of maximum 24-hour rains to the rainfall stations which do not report by telegraph, so that the record of heavy falls in any certain 24-hour period is incomplete. At Elba, Ala., the place having the greatest fall, the following note is entered against the record for the 14th: "14 inches was measured at 4 p. m.," the record after that hour is estimated. Other indirect evidence points toward the rainfall of the 14th as being the greater of the two days, notwithstanding the evidence of the tabulated values in Table 2.

UPPER-AIR OBSERVATIONS

As so frequently happens by reason of cloudy skies and rain, upper air observations are not forthcoming when most needed. I gather from the free air observations prior to the rains of March 12–15 that there may have been in the beginning something like a mass movement of the air over the east Gulf States from the west or southwest. In the absence of definite information with respect to the upper air, let us turn our attention to the surface winds and such inferences as may be drawn from them as to the direction of the upper winds.

As early as the 10th of March surface winds over Alabama were uniformly from the northeast and of continental origin. On the 11th they had become easterly, and on the 12th, when general rains began, they had shifted to southeast and were of oceanic origin. On this date the barometric gradient due to the oceanic anticyclone acting jointly with the gradient due to a cyclone centered over eastern Colorado doubtless caused an acceleration of the southeast winds and they continued throughout that and the following day.

The upper winds on the 13th, 14th, and possibly for a part of the 15th must have been from a westerly quarter, basing this statement on the well-known turning of the surface winds with altitude.

As previously stated, the development and movement of the middle Mississippi Valley cyclone of the 15th must have resulted in a more northerly component being injected into the upper winds over east Gulf States on that date.

The longer axis of the area of heavy rains on the 14th was in a n./s. direction, and on the 15th it was ne./sw. when the areas contiguous to Alabama are considered. The isohyetal chart (fig. 1), however, gives the impression that the heavy rains were local to the watersheds under discussion.

It may be asked, how was the excessive rain distributed throughout the 24 hours? The answer for a single station having an automatic register is found for Mobile, Ala. Excessive rains occurred at that station on March 12, 13, and 14. The maximum amount for any 24 hours was 11.59 inches on the 14th and 15th. The excessive rate began at 3:46 a. m. and ended temporarily at 4:13 a. m. The rate continued as shown in the exhibit below:

Mobile, Ala.

Date	Excessive rate— Began	Excessive rate— Ended	Amount	Rate per minute
Mar. 14	3:46 a	4:13 a	0.76	0.028
Do	5:08 a	5:58 a	.95	.019
Do	5:58 a	6:48 a	.66	.013
Do	6:48 a	7:38 a	.82	.016
Do	7:38 a	8:28 a	.85	.016
Do	8:28 a	9:18 a	1.03	.021
Do	9:18 a	10:08 a	.68	.014
Do	9:54 p	10:56 p	1.48	.024

The bulk of the excessive rain at Mobile fell therefore during the 7 hours and 11 minutes that elapsed between 3:46 a. m. and 10:56 a. m. of the same day. During that time 6.71 inches fell or at the rate of 0.016 inch per minute. Naturally there were occasions during that time when the average rate was greater, as shown by the following tabulation:

Time	Maximum amount	Rate
	Inch	*Inch per minute*
5 minutes	0.40	0.08
10 minutes	.71	.07
15 minutes	.97	.06
30 minutes	1.67	.06
60 minutes	2.32	.04
120 minutes	2.66	.02

For comparative purposes the record of the greatest 24-hour rainfall in the United States which occurred at Taylor, Tex., September 9 and 10, 1921, is given below: [1]

Time	Maximum amount	Rate
	Inch	*Inch per minute*
5 minutes	0.72	0.144
10 minutes	1.12	.112
15 minutes	1.47	.098
30 minutes	2.56	.085
60 minutes	4.25	.071
120 minutes	7.51	.063

The 24-hour rainfall at Taylor was 23.11 inches; of this amount there is a continuous automatic record for the 3 hours 6:42 p. m. to 9:42 p. m. of the 9th and the catch during that time was 10.44 inches, or an average rate of 0.058 inch per minute. As in the previous case I give the maximum rates for the storm during 5, 10, 15 minute periods, etc.

The rains at Taylor were associated with a thunderstorm and this was also the case at Mobile; we are therefore able to conclude that the exceptionally heavy rains in both cases were the result of violent convective action.

RECAPITULATION

The immediate and direct cause of the overflow was the heavy downpours of rain on March 14 and 15 in the basins of the Choctawhatchie and Conecuh Rivers at a time when due to previous rains the soil was saturated with water and the streams were at bankful stages. Other contributing causes were the slight slope of the rivers in that part of Alabama and consequently the very slow disposal of the water by the trunk streams. The fact that the local drainage at Elba and Brewton permitted a large volume of water to be passed into the trunk stream at those points undoubtedly was a very considerable factor in the flooding that took place.

[1] cf. McAuliffe J. P., Excessive rainfall and floods at Taylor, Tex., Mo. Wea. Rev. 49: 496–97.

551.578.1 (759)

SOME CHARACTERISTICS OF THE RAINY SEASON AT TAMPA, FLA.

By WALTER J. BENNETT, Meteorologist

The conventional and convenient division of the year into four seasons of three months each is not entirely satisfactory for central Florida. Considering temperature, we have winter, including December, January, and February; spring, March, April, and May; but when we come to summer we must take in four months, June, July, August, and September, for September averages only 1.4° cooler than August. This leaves us only two months, October and November, for the autumn.

Considering precipitation, the four summer months stand together because of abundant rainfall. Almost two-thirds (61 per cent) of the average annual rainfall occurs in these four months—that is, in one-third of the year. September, the driest of the four, has more than twice as much rain as May or October. During this season the probability of a measurable amount of rain on any day is 52 per cent, or a little better than one day out of every two; and the probability of a trace or more of rain is 64 per cent, or not quite two days out of every three. During the other eight months the probability of 0.01 inch of rain any day is 21 per cent, or only one day out of five; and of trace or more of rain 29 per cent,